Distribution and Movement of Juvenile Paddlefish in a Mainstem Missouri River Reservoir

K. Dawn Roush[a], Craig P. Paukert[b], and W. Stancill

U.S. Fish and Wildlife Service (KDR and WS)
Great Plains Fish and Wildlife Management Assistance Office
420 South Garfield Avenue, Suite 400
Pierre, South Dakota 57501 USA

and

Department of Wildlife and Fisheries Sciences (CPP)
PO Box 2140B
South Dakota State University
Brookings, South Dakota 57007 USA

ABSTRACT

Hatchery-raised paddlefish (*Polyodon spathula*) were implanted with ultrasonic transmitters and tracked from August to November 1998 and March to November of 1999 and 2000 to determine diel movements and seasonal distribution in Lake Francis Case, South Dakota. Juvenile (340 to 432 mm eye to fork length) paddlefish (N=32) exhibited variable movement patterns but remained in the upper reservoir reaches throughout the three-year study. Movement rates ranged from 35 to 3,464 m/h with 90% of all locations in the upper third (51 km) of the reservoir. Increased movement rates were weakly correlated with increased water temperature (r=0.16, P=0.04). Daytime paddlefish movement peaked in July and August. However, diel movements were variable among seasons. In spring, movement rates did not differ among diel periods, whereas summer movements were lower during crepuscular periods and fall movements were lowest during the day. Although paddlefish were stocked at two locations in Lake Francis Case, they appeared to disperse and use reservoir areas similarly.

INTRODUCTION

Paddlefish (*Polyodon spathula*) historically inhabited large rivers throughout the midwestern Unites States, including the Missouri River (Graham 1997). Habitat loss and the construction of dams were partially responsible for paddlefish declines throughout the past 100 years (Unkenholz 1986). Specifically, construction of dams has eliminated spawning sites or blocked spawning migrations, eliminated backwater areas, and altered water flow regimes (Graham 1997).

Paddlefish distribution and movement have been studied in riverine environments (Rosen et al. 1982, Southall and Hubert 1984, Moen et al. 1992, Zigler et al. 1999) and more recently in reservoirs (Paukert and Fisher 2000, Paukert and Fisher 2001b, Stancill et al. 2002). However, these studies focused on adult fish. There is a paucity of information on juvenile paddlefish distribution and movement. Pitman and Parks (1994) documented large migrations of juvenile paddlefish into upstream rivers immediately after stocking in a Texas reservoir.

[a] Corresponding author present address: Michigan Department of Environmental Quality, Constitution Hall, PO Box 30273, Lansing, Michigan 48909, E-mail: roushd@michigan.gov

[b] Present address: Southwest Biological Science Center, U.S. Geological Survey, 2255 North Gemini Drive, Flagstaff, Arizona 86001

Seasonal and diel paddlefish movements have received little attention, particularly for reservoir populations. Paddlefish in the upper Mississippi River exhibited variable diel movements, depending on season (Zigler et al. 1999), whereas paddlefish in an Oklahoma reservoir moved twice as much at night during the summer months (Paukert and Fisher 2000). Seasonal distribution studies typically focus on spring spawning migrations (Purkett 1961, Lein and DeVries 1998, Paukert and Fisher 2001b), with little attention given to other seasons. In particular, we found no studies on juvenile paddlefish seasonal distribution within a reservoir environment.

Dispersal of fish after stocking is an important aspect of fisheries management in larger water bodies. The evaluation of dispersal after stocking is necessary for evaluating stocking success (Parsons and Pereira 1997). Research on other species has suggested that stocking should be conducted at multiple release sites to help dispersion (Parsons and Pereira 1997, Peery and Bjornn 2000). However, to our knowledge, no one has evaluated dispersal of juvenile paddlefish after stocking.

The primary objectives of this study were to determine the seasonal and diel movement patterns of juvenile paddlefish in a reservoir system. In addition, we wanted to determine distribution and dispersal after stocking at two different locations.

STUDY SITE

Lake Francis Case is a mainstem Missouri River hydropower impoundment that was formed by the closure of Fort Randall Dam in 1952. The reservoir is 170 km long, has a mean width of 1.9 km, and a surface area of 320 km^2. Secchi disk readings during summer range from 4.5 m in the lower reaches to 1.0 m in the upper reaches. Side channels, backwaters, oxbows, and other riverine habitat were lost after impoundment. The White River is the only major tributary to Lake Francis Case and may be a historical spawning location for paddlefish (Stancill et al. 2002). Lake Francis Case did provide a recreational paddlefish fishery prior to closure of Big Bend Dam, which is immediately upriver from Lake Francis Case, but low recruitment has led to prohibition of harvest (Unkenholz 1986). Paddlefish have been stocked in Lake Francis Case since the 1970s in efforts to restore a recreational fishery in the lake (Graham 1997).

METHODS

Thirty-two juvenile paddlefish (340 to 432 mm eye to fork length, EFL; Ruelle and Hudson 1977) were reared at Gavins Point National Fish Hatchery, South Dakota and surgically implanted with 50-month, abdominal, ultrasonic telemetry tags (Sonotronics model CT-82-3) in July 1998. Half of the implanted fish were stocked into the White River approximately 22 km upstream from the confluence of Lake Francis Case. The remaining fish were stocked at the American Creek boat ramp (Figure 1).

Juvenile paddlefish were relocated from 19 August to 5 November 1998, 15 March to 5 November 1999, and 7 March to 30 October 2000. Because the entire reservoir could not be searched during each sampling trip, we separated the reservoir into four zones (Figure 1), and two zones were randomly selected and searched each month. Fish locations were determined by using a directional hydrophone and digital receiver. When the transmitter signal was equally strong in all directions, we recorded the fish location with a global positioning receiver.

To determine diel movement patterns, we relocated as many paddlefish as possible every hour for two of the four diel periods (i.e., dawn, day, dusk, and night). Dawn was defined as one hour prior to and one hour after sunrise; dusk was defined as one hour prior to and one hour after sunset. This tracking was conducted three times from August to September 1998, 13 times from March through October 1999, and 13 times from March through October 2000.

To facilitate analysis and increase sample size, we combined months into three seasons: spring (March - May), summer (June – August), and fall (September – November). Years were also combined to increase sample size and because we were not interested in individual year effects, but general distribution and movement patterns. Because not all seasons were sampled in 1998, we eliminated this year from our relative abundance analysis. We calculated an index of relative abundance of telemetry locations (i.e., catch per unit effort [CPUE]) as the number of locations of an individual fish divided by the number times the reservoir zone was sampled (because all zones were not sampled equally). For example, during fall, fish number 237 was located four times in five sampling trips to zone 1 for a CPUE of 4/5=0.80. The same fish was located once in four sampling trip to zone two, for a CPUE of 1/4=0.25. Because each fish was located only once per trip, maximum CPUE was 1.0.

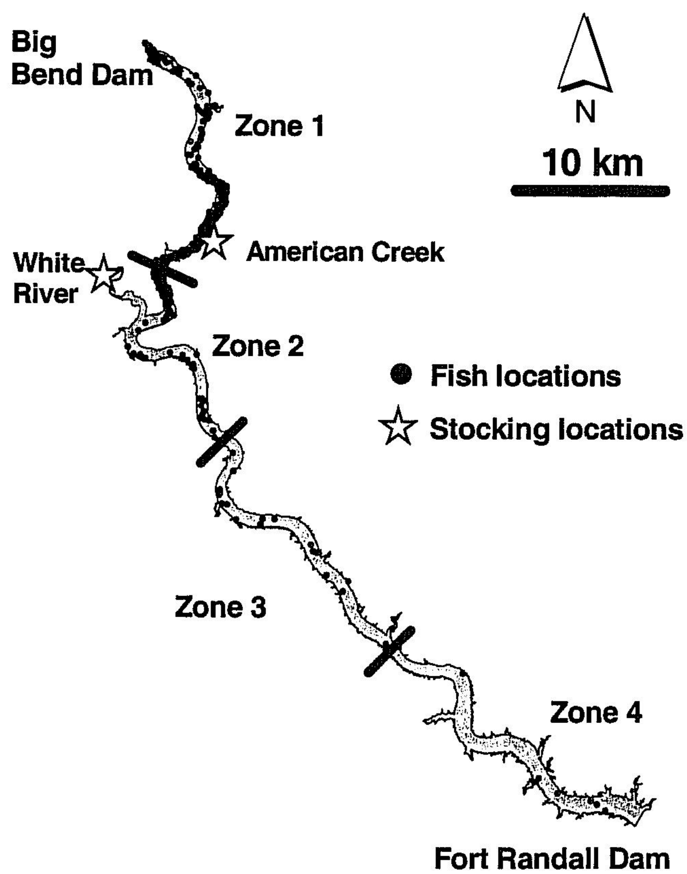

Figure 1. Daily paddlefish locations from August 1998 to October 2000 for 32 juvenile paddlefish implanted with ultrasonic transmitters in Lake Francis Case, South Dakota. Dark bars delineate the four sampling zones. Fish were originally stocked in the White River and American Creek, as denoted by stars.

A repeated-measures analysis of variance was used to determine if CPUE differed among reservoir zones for each season and to determine if mean movement rates differed by diel period, or by seasons, or if mean daily movement differed among months. Because multiple observations for each individual fish were recorded, the fish was the repeated variable. This analysis was also used to determine if direction of paddlefish movement (upstream, downstream, or remaining within the same river km) was related to water flows or season. All analyses used a mixed model (PROC MIXED in SAS; Littell, et al. 1996) because this analysis does not assume of homogeneity of variances.

Spearman rank correlations were used to assess the relationship between paddlefish movement rates and water inflow and temperature from Big Bend Dam (which was recorded at a gauging station located on the dam). A Wilcoxon rank sum test was used to determine if the maximum, minimum, and median river km used by the fish differed between the two stocking locations (White River and American Creek).

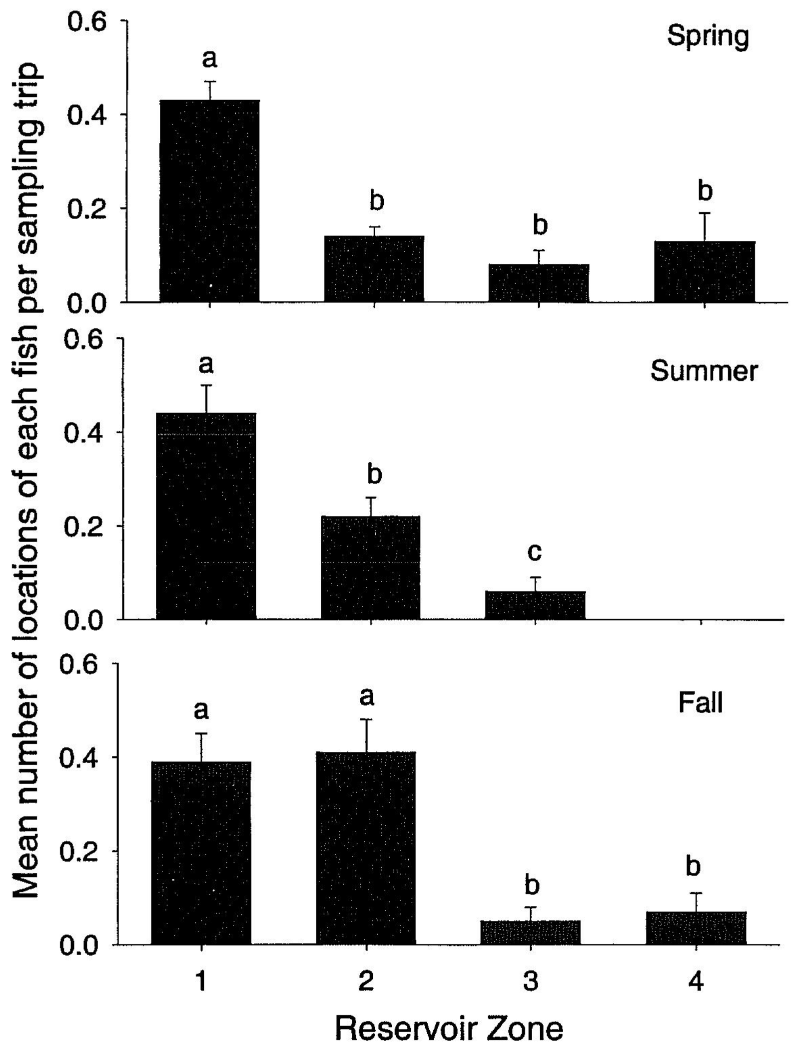

Figure 2. Catch per unit effort (mean number of locations per fish per sampling trip) of 32 juvenile paddlefish located from March to October of 1999 and 2000 in Lake Francis Case, South Dakota.

RESULTS

From August 1998 to October 2000, 530 daily locations were collected from 32 fish. In addition, 255 hourly locations were collected from 19 individual fish. Of the 530 daily locations, 474 locations (90%) were in the upper 30 km of the 170 km long reservoir (Figure 1). Throughout the study, overall paddlefish movement ranged from 16 river km to 133 river km, with an average of 36 km. A two-way ANOVA revealed that paddlefish use of reservoir zone was not consistent among seasons (season x reservoir zone interaction: F=3.74, df=6, 352, P=0.001). Therefore, all further analyses of reservoir use were separated by season. Reservoir zone one (upper reservoir) had the highest CPUE in spring (F=13.57, df=3,120, P<0.001) and summer (F=28.75, df=3,120, P<0.001), whereas both reservoir zones 1 and 2 had the highest CPUE during fall (F=13.80, df=3,112, P<0.001)(Figure 2).

Individual movement rates during the day ranged from 35 m/h to 2,464 m/h throughout the study. Mean daily movement rates varied from 342 m/h in September to 851 m/h in July (Figure 3). Movement rates typically were highest in July and August and were similar from March to June and September to October (F=5.24, df=7,34, P<0.001). Movement rates did increase with water temperature (r=0.16, df=181, P=0.035), but the correlation was weak. Even at the highest water temperature (22.2°C), paddlefish movement rates ranged from 59 to 786 m/h, whereas movement rates at the lowest water temperature (1.7°C) ranged from 127 to 495 m/h. However, diel movement rates were not consistent across seasons (diel period x season interaction: F=6.02, df=6,18, P=0.001) and thus further analysis was separated by season. Movement rates did not differ across diel periods for spring (F=2.64, df=3,13, P=0.095), whereas movement rates were lowest during dawn in summer (F=6.29, df=3,19, P=0.004), and during the day in fall (F=4.89, df=3,8, P=0.03)(Figure 4). Juvenile paddlefish movement was not related to inflows from Big Bend Dam for spring (r=-0.19, df=77, P=0.085), summer (r=0.11, df=147, P=0.166), or fall (r=-0.05, df=52, P=0.693). Direction of paddlefish movement (i.e., up, down, or sedentary) was not related to flows from Big Bend Dam (F=0.53, df=2, 63, P=0.593), regardless of season (direction x season interaction: F=0.53, df=3,49, P=0.664).

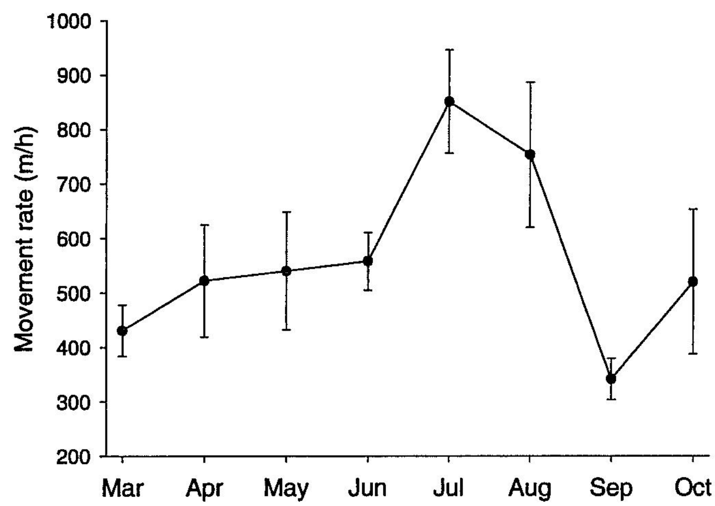

Figure 3. Mean daily movement rates (m/h) from March to October 1999 and 2000 for 32 juvenile paddlefish implanted with ultrasonic transmitters.

Juvenile paddlefish stocked at American Creek and at the White River both distributed throughout the reservoir. There was no difference in the median river km used by American Creek and White River fish (χ^2=0.06, P=0.806), the maximum river km used (χ^2=0.24, P=0.623), or minimum river km used (χ^2=0.76, P=0.383). Regardless of stocking location, juvenile paddlefish used reservoir areas similarly. However, both stocking locations were in the upper one third of the reservoir.

DISCUSSION

Juvenile paddlefish in Lake Francis Case remained in the upper reservoir reaches throughout our study. Within-reservoir movements are not well known, particularly for juvenile paddlefish. Although we did not measure zooplankton densities in the reservoir, lower reservoir reaches typically have lower zooplankton densities (Marzolf 1990) and may possibly explain the use of the upper reservoir of Lake Francis Case. Although the majority of fish locations were in the upper reaches of the reservoir, some fish utilized 130 km of the 170 km reservoir length, suggesting individuality of fish distribution. Upstream migrations and congregations in reservoirs are common for adult paddlefish during spring spawning migrations; however these fish typically move to lower reservoir areas during other seasons (Paukert and Fisher 2001a, b, Stancill et al. 2002). This is also true for juvenile paddlefish (Pitman and Parks 1994). Paddlefish typically prefer deeper water (Pitman and Parks 1994, Zigler et al. 1999), suggesting that paddlefish in Lake Francis Case would use the deeper, lower reservoir areas. Instead, these juvenile fish remained in the upper reservoir reaches during all seasons sampled. Sampling for age-0 paddlefish in Lake Sakakawea, North Dakota was conducted in the upper reservoir areas during summer (Fredricks and Scarnecchia 1997), which may be appropriate for Lake Francis Case.

Individual paddlefish movement was variable and ranged to over 2,000 m/h, which was similar to adult paddlefish in the upper Mississippi River (up to 1,547 m/h; Zigler et al. 1999). In an Oklahoma reservoir, adult (843-1,000 mm EFL) paddlefish moved up to 4,000 m/h during summer (Paukert and Fisher 2000). Paddlefish in open systems typically are highly mobile, making movements of over 2,000 km (Rosen et al. 1982). In the Neches River, Texas, paddlefish of similar size to the fish in our study (348 to 500 m EFL) moved as much as 270 km (Pitman and Parks 1994). In addition, movement rates were marginally related to water temperature, which is similar to other fishes (e.g., Hergenrader and Hasler 1967). However the weak relationship suggests that factors other than water temperature influence paddlefish movement.

Diel movements varied by season in Lake Francis Case, with no difference in spring movement across diel periods, reduced crepuscular movement during summer, and reduced daytime movement during fall. In the Mississippi River, spring and fall adult paddlefish movements were greatest at nighttime and least during the daytime, whereas summer movements did not differ among diel periods (Zigler at al. 1999). During summer in an Oklahoma reservoir, paddlefish moved about twice as much during the night compared to the day (Paukert and Fisher 2000). Although these studies suggest variable movement for different water bodies, fall movements were lowest during the daytime in both the Mississippi River and Lake Francis Case, two regulated, northern U.S. waters.

Juvenile paddlefish movement was not related to water flow during any season in Lake Francis Case. In Keystone Reservoir, Oklahoma, summer nighttime movement rates of adult paddlefish were lower when water flows were higher (Paukert and Fisher 2000). Although spring water level flows may trigger spawning migrations of adult paddlefish (Purkett 1961, Wallus 1986, Hoxmeier and DeVries 1997, Paukert and Fisher 2001b), water flow did not influence juvenile paddlefish in Lake Francis Case. In contrast, other studies have suggested that juvenile paddlefish may still migrate upriver during spring flows, although they likely do not spawn (Pitman and Parks 1994, Paukert and Fisher 2001b).

Juvenile paddlefish stocked at two locations in Lake Francis Case apparently distributed throughout the reservoir similarly. Although we did not document site fidelity to stocking locations, adult paddlefish in Lake Francis Case exhibit site fidelity to their presumed historical spawning areas (Stancill et al. 2002). Paddlefish are highly mobile by nature (Rosen et al. 1982) and thus presumably will disperse from their original stocking locations. Pitman and Parks (1994) concluded that juvenile paddlefish migrate considerable distances after stocking but recommended stocking paddlefish upstream of mainstem reservoirs close to sources of high flows. In a reservoir systems such as Lake Francis Case, stocking location appeared to have no influence on paddlefish dispersal, at least for the two upper reservoir stocking locations in our study.

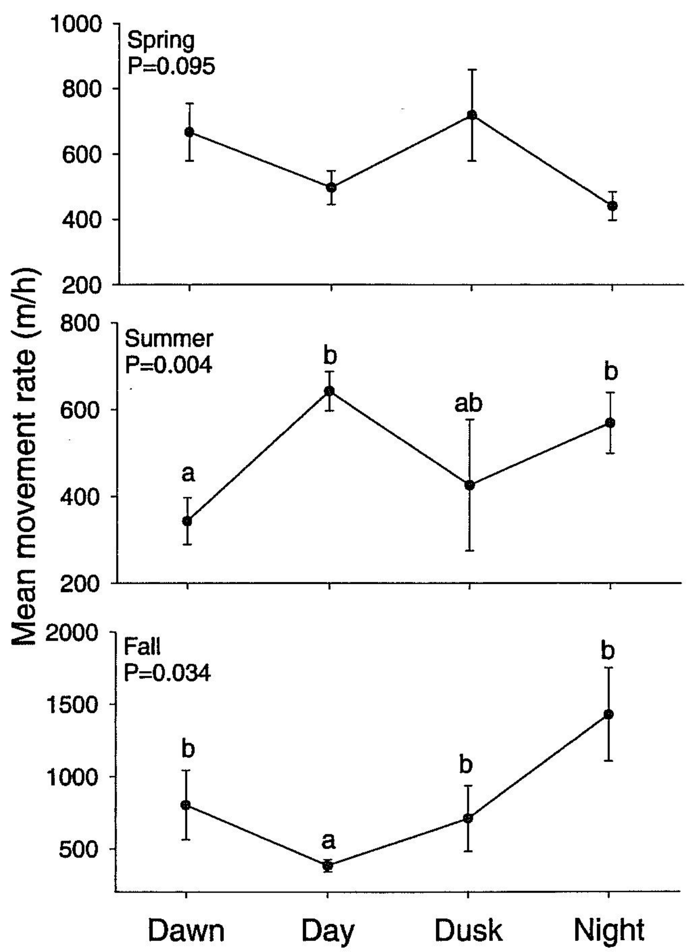

Figure 4. Mean diel movement rates (m/h) for juvenile paddlefish located approximately once per hour in spring, summer, and fall 1998-2000.

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